Cities 72 (2018) 189–200

Contents lists available at ScienceDirect

Cities

journal homepage: www.elsevier.com/locate/cities

Mapping and analyzing socio-environmental vulnerability to coastal hazards induced by climate change: An application to coastal Mediterranean cities in France☆

Asimina Mavromatidi*, Elodie Briche, Cécilia Claeys

Aix Marseille Univ., IRD, LPED, 3, Place Victor Hugo, 13331 Marseille Cedex 3, France

ARTICLE INFO

Keywords:
Climate change
Coastal sensitivity
Social vulnerability
Indices
Mediterranean French cities
GIS

ABSTRACT

The densely populated cities of continental Mediterranean France, which are prone to erosion, are facing a potentially multi-hazard threat, due to a rise in sea-level that is expected to increase by between 0.07 and 0.12 m during the 21st century. The aim of this study is the superimposition of two widely used empirical indexes – the Coastal Sensitivity Index and the Social Vulnerability Index. In this research, the CSI is based on the following 6 parameters: geomorphology, coastal slope, sea-level rise, shoreline changes, mean tidal range and significant wave height, while the SVI used is constructed from 9 parameters: population $<$ 14 years old, population over 75 years old, women, single parent families, families with more than two children, tenants, average density (inhabitants/km^2), unemployed population, population with no education and foreigners. The research was initially conducted on the French Mediterranean coast, where environmental inequality was observed, and led to the selection of 3 areas of interest for a further investigation in finer scale (municipality/*département*/coastal district scale). It was noted that in certain cases the socio-environmental vulnerability of a municipality (as a whole) differed from the one presented in its coastal district. Thus, the socio-environmental vulnerability of a place is related to the study's scale, and the interest lies in the recognition of the most vulnerable coastal districts of cities, in conjunction with coastal sensitivity, in order to prioritize the efforts for coastal management.

1. Introduction

During the last century, coastal Mediterranean urbanization increased dramatically, with an urbanization rate of nearly 65%, which is estimated to increase to 79% by the year 2030 (Brauch, 2003; Plan Bleu, 2015; UN, 2000), mostly due to the high concentration of natural and socio-economic values located on coasts (Mitchell, 1999; Sachs, Mellinger, & Gallup, 2001; UNCHS, 2001). An estimated 40.8% of the European population live in near-coastal zones, while the population of the Mediterranean coastal regions increased from 95 million in 1979 to 143 million in 2000 (Plan Bleu, 2015). In France, 50% of the population is living within 50 km of the sea (Eurostat, 2012). An anticipated sea-level rise, as a result of increasing global temperature, is expected to accelerate coastal dynamics (EM-DAT, 2012; IPCC, 2013; NOAA, 2016): the predictions of future global sea-level from several climate models range between 0.25 and 0.98 m by the year 2100 (Cazenave & Nerem, 2004; IPCC, 2013), while for the Mediterranean Sea a rate between 0.07 and 0.12 m on average will possibly be noted during the 21st century (Gualdi et al., 2013). Among the significant negative effects of future sea-level rise are coastal erosion, frequent and intensified cyclonic activity and associated storm surge flooding, that may affect the coastal zones. Faced with this threat, Mediterranean municipalities, identified as "hot-spots" (IPCC, 2013; Plan Bleu, 2015) are obliged to investigate alternative solutions for sustainable urban planning and development (EM-DAT, 2012; Mavromatidis, Mavromatidi, & Lequay, 2014), in order to improve their capacity to adapt to this new climate change reality (Houghton et al., 2001). The first step of this investigation lies in understanding and incorporating the notion of vulnerability as a powerful analytical tool (Adger, 2006; Plan Bleu, 2015).

As Levefre (1991) notes, "space is a social product or a complex social construction", which influences spatial practices (Mavromatidis, 2012). The social, political and economic power relations based on which we create our building environment (material processes), affect our relative

☆ The research was conducted in LPED Laboratory- "Laboratoire Population Environnement Développement" and in MC3-Meditteranean cities and climate change network. This work is been carried out thanks to the support of the A*MIDEX project (no. ANR-11-IDEX-0001-02) funded by the "Investissements d'Avenir" French Government program, managed by the French National Research Agency (ANR).
Asimina Mavromatidi would like to thank IKY – State Scholarship Foundation of Greece for the financial support during the Erasmus Placement Program.
* Corresponding author.
E-mail addresses: semimavr@gmail.com (A. Mavromatidi), elodie.BRICHE@univ-amu.fr (E. Briche), cecilia.claeys@univ-amu.fr (C. Claeys).

http://dx.doi.org/10.1016/j.cities.2017.08.007
Received 26 October 2016; Received in revised form 11 July 2017; Accepted 10 August 2017
Available online 07 September 2017

vulnerability within an environment that is co-created by nature and society (Mavromatidis and Mavromatidi, 2012; Mavromatidis et al., 2014). Although most hazards are natural, disasters – expressed as the activation of a dormant hazard, − are not natural and therefore cannot exist without humans (O'Keefe, Westgate, & Wisner, 1976; Steinberg, 2000; Wisner, Blaikie, Cannon, & Davis, 2004). Thus, they must mainly be examined as the outcome of human actions – as the "actualization of social vulnerability" (Lewis, 1999).

According to Lélé (1991) the awareness that the ecological sustainability of the people-nature interplay can be affected by the combination of ecological and social conditions can contribute noticeably to the environment development debate. Any conflict in social and power relations is revealed through material practices as conflict within the environment, in the form of inequalities in risk exposure (Harvey, 1996; Oliver-Smith, 2004). Therefore, coastal vulnerability is about placing the people who may experience disaster or potential hazard at the heart of analysis and strategic planning of coastal cities, in order to prevent human, economical or environmental losses, caused by sea-level rise.

In terms of determining the concept of vulnerability, the development of official statistics since the 19th century has enabled the link between socio-economic insecurity and exposure to degraded living and working environments to become apparent (Fassin, 2009). The notion of "environmental inequalities" experienced its latest manifestation in the wake of the American Civil Rights movement (Taylor, 2000). The starting point was the link between environmental vulnerability (exposure to natural and anthropogenic risks, difficult access to environmental amenities) and social vulnerability (poverty, poor access to education and membership of ethno-racial minorities). Such empirical observations – also made in Europe – gave rise to theoretical considerations in terms of environmental justice (Fraser, 2005) and intersectionality (Yuval-Davis, 2015), as a "plurality of the logic of domination" (Fassin, 2015). Conversely, Ulrich Beck (1992) in "Risk Society" argues that the most vulnerable populations in terms of exposure to a hazard are not always the most disadvantaged socially and economically, questioning the systematic nature of the accumulated social and environmental vulnerability. In doing so, he highlights the restructuring of traditional social inequalities in the context of contemporary risks. Beyond the theoretical controversy, these two readings of vulnerability enable us to see the plurality of actual or potential situations.

The presence of social vulnerability, coupled with the absence of coastal sensitivity, would correspond to a situation of "strict" social inequalities. Situations of socio-environmental vulnerability which are characterized by a combination of coastal sensitivity and social vulnerability tend to lead to environmental inequalities (Deldreve, 2015). Conversely, an absence of both coastal sensitivity and social vulnerability could in theory create a situation of environmental justice (Taylor, 2000). However, the absence of both coastal sensitivity and social vulnerability at a local scale may also hide socio-spatial segmentations on larger scales, which are especially frequent in coastal cities (Deboudt, 2010). Finally, when individuals are subjected to environmental vulnerabilities while escaping any social vulnerability, the situation could correspond to Beck's above-mentioned notion of the "Risk Society" – a situation of "strict" coastal sensitivity. However, the economic, social and cultural capital of these individuals permits them to be characterized by a specific action capability (Nussbaum, 2003), allowing them to feedback on their environmental vulnerability (to protect themselves, to move, to influence public policies, in particular).

Understanding "vulnerability paths" (Magnan & Duvat, 2015) – or in other words the processes whereby societies produce disasters – has increasingly become a topic of scientific research. Several approaches in the form of indexes have been proposed in order to predict the physical process of the coastal zone, under the influence of anticipated sea-level rise at national and regional level (Mavromatidi & Karymbalis, 2016; Karymbalis et al., 2012; Karymbalis, Chalkias, Ferentinou, Chalkias, & Magklara, 2014; Diez, Perillo, & Piccolo, 2007; Pendleton, Thieler, & Williams, 2004; Thieler & Hammar-Klose, 1999; Gortnitz, 1991). However, in most cases, coastal sensitivity to marine processes is approached only on the basis of topographic, geological, oceanographic and meteorological parameters, without taking into consideration the human population who may be directly or indirectly influenced (Adger, 1999; Alwang, Siegel, & Jorgensen, 2001). Many researchers who dealt with hazards in coastal cities highlighted the need to include demographic and economic variables in order to create a more useful composite index for the evaluation of vulnerability (Clavano, 2012; Diez et al., 2007; Gornitz, Daniels, White, & Birdwell, 1994; Lichter & Felsenstein, 2012). In this context, investigations have been made relating to the evaluation of risk in coastal zones by taking into account not only natural, but also socio-economic variables (Gorokhovich, Leiserowitz, & Dugan, 2014; Plan Bleu, 2015; Reyes & Blanco, 2012; Szlafsztein & Sterr, 2007), including risk perception analysis (Meur-Ferec, Deboudt, & Morel, 2008, Rulleau, Rey-Valette, Flanquart, Hellequin, & Meur-Férec, 2015).

This current research provides a conceptual link in improving our understanding of the connection between coastal sensitivity and social vulnerability, on the scale of Mediterranean France (region, county, municipality). For this reason, the calculation methodologies of two widely used empirical indexes - the CSI of Shaw, Taylor, Forbes, Ruz, and Solomon (1998) and the SVI of Flanagan, Gregory, Hallisey, Heitgerd, and Lewis (2011) - are applied. The aim of the study was to use free data in order to examine the coastal sensitivity and vulnerability of our study area, as a rapid, preliminary way to identify susceptible areas, in county and municipality-level. The conceptualization of the procedures that cause changes can be a good policy framework to determine the coastal vulnerability objectives of a social-ecological system. Since human actions and social structures are integral to nature (Adger, 2006), this comparison can be useful in providing recommendations for the efficient use of existing methods for mapping and analyzing the vulnerability of coastal Mediterranean cities to climate change and sea-level rise.

2. Materials and methods

2.1. Historical retrospection of the study area

The French Mediterranean coastline is 1703 km long and marked by contrasting historical heritage (Fig. 1). To the East, the *Côte d'Azur* (the Riviera), mostly rocky, with a sequence of small bays and headlands, was soon converted into an elitist seaside resort: the English aristocracy played a pioneering role in this region, way back in the 18th century (Bottaro, 2014). Despite the relative democratization of leisure, this region is still characterized to this day by the elitism of its seasonal and permanent vacationers. In the West, the *Languedoc-Roussillon* has long been an agricultural hinterland and its coastal lagoons have been occupied by traditional small fishing crafts. Its sandy coasts were deemed inhospitable, due to the presence of mosquitoes (vectors of fever), that exposed local populations to particularly high mortality rates (Sagnes, 2001). However, taking advantage of the modernization of the post-war policies, the *Languedoc-Roussillon* region was the subject of an ambitious development program. Drainages, mosquito control, impoundments and urbanization, initiated in 1960 by the Interministerial Mission Racine turned *Languedoc-Roussillon* into the symbol of mass tourism. Several cities operated as seaside resorts (*La Grande Motte*, *Le Grau du Roi*, *Cap d'Agde*, *Valras Plage*). Between *Languedoc-Roussillon* and the *Côte d'Azur* a composite mosaic of territories can be found. The *Rhône* Delta is home to several natural reserves and the Camargue Regional Park was designed in 1970 as a green buffer zone between the tourist urbanization of *Languedoc-Roussillon* and the petrochemical industry in the *Etang de Berre* (Picon, 2008). The *Etang de Berre*, the largest coastal lagoon in Europe, has indeed been invested by the petrochemical industry since the 1930s (Daumalin, 2013). Connected to the sea by the *Canal de Caronte*, *the Etang de Berre* is connected to the port of the city of Marseille and its extensions up to the *Fos* container terminal. Weakened by the economic crisis, these municipalities are struggling between the modernization of their port infrastructure and seaside reconversion. These coastal landscapes all remain strongly influenced by their industrial heritage (Bertran de Balanda, 2014).

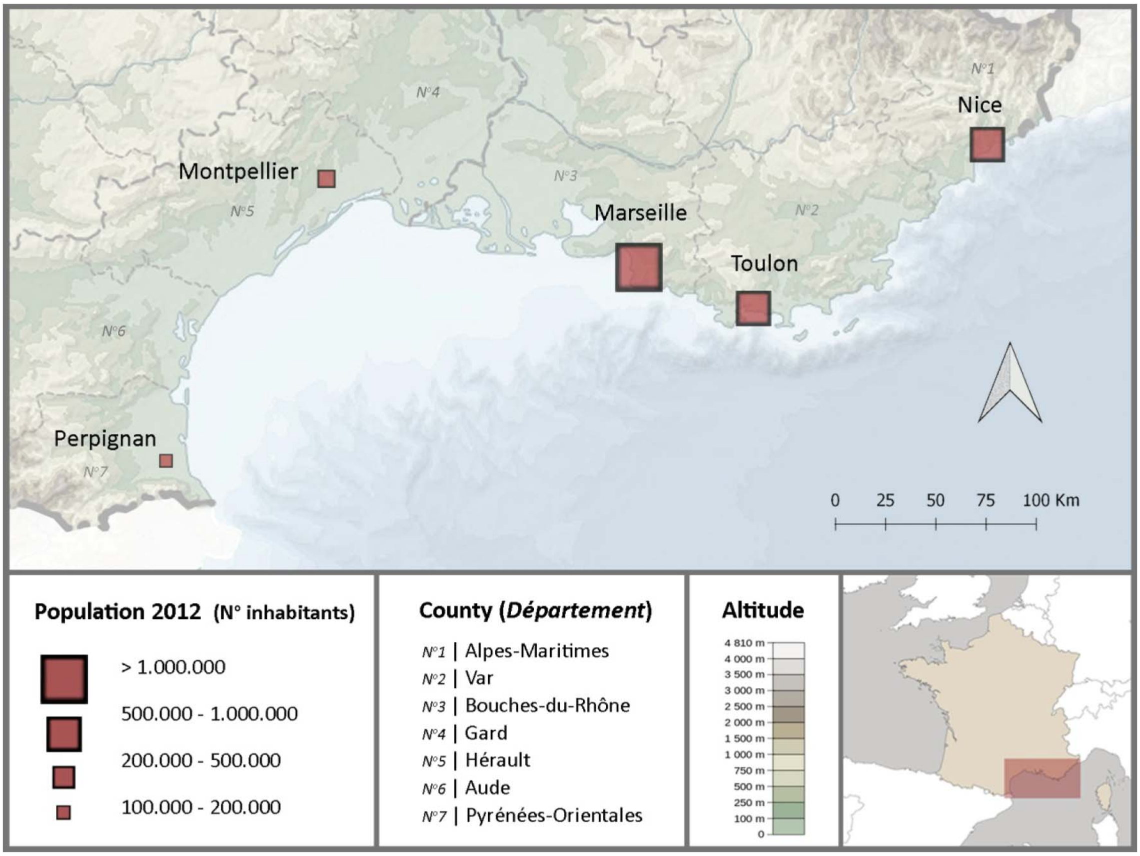

Fig. 1. Map of study area.
Source: INSEE (2010), NASA STRM (2014), Amante and Eakins (2009), modified by authors.

2.2. Determining the framework of sensitivity in natural hazards

An early attempt to create a coastal vulnerability index to climate change, as a relative measure of the system's physical susceptibility to the effect of sea-level rise, was proposed by Gornitz and Kanciruk (1989), regarding inundation and susceptibility to erosion (Jeftic, Milliman, & Sestini, 1992). The United States Geological Survey (USGS) later modified and applied the coastal vulnerability index into an analysis of various shorelines of the US (Thieler & Hammar-Klose, 1999). The index is based on the physical variables of a coastal area, such as coastal geomorphology, coastal relief, shoreline displacement, relative sea-level change, tidal range and significant wave height. It has been widely used to evaluate the susceptibility of coasts in Canada (Shaw et al., 1998), the USA (Pendleton et al., 2004; Thieler & Hammar-Klose, 1999), Brazil (Diez et al., 2007), Europe (Doukakis, 2005), Greece (Karymbalis et al., 2012; Karymbalis et al., 2014).

Thus, the CSI proposed for the Canadian coast by Shaw et al. (1998) was applied in the study area on the basis of topographic and geo-environmental information, and utilizing GIS technology. CSI is calculated as the square root of the product of six variables, classified from 1 to 5 according to Table 1, and divided by their total number (Eq. (1)):

Formula for CSI calculation

$$(\mathrm{CSI}) = \sqrt{\frac{a^*b^*c^*d^*e^*f}{6}} \tag{1}$$

where: (a): geomorphology, (b): coastal slope, (c): relative sea-level rise, (d): shoreline changes, (e): mean tidal range and (f): mean significant wave height.

The coast's calibration limits in five categories, proposed by Pendleton et al. (2004), as well as the sources for the data of each parameter are presented in Table 2.

2.3. Encapsulating the complex concept of social vulnerability

In the 1970s, when researchers acknowledged that there are socio-economic factors which affect competencies in responding and recovering of geographical areas in natural events, the notion of social vulnerability was introduced within the scope of disaster management (Flanagan et al., 2011). Social vulnerability originates from a social policy based on various characteristics such as gender, education, socio-economic status, ethnicity, age, employment, income, education level, population growth, human settlements (housing type and construction) and other dynamic factors (Bolin & Stanford, 1998; Buckle, Marsh, & Smale, 2000; Burton & Cutter, 2008; Dwyer, Nielsen, Day, et al., 2004; Enarson, Fothergill, & Lohri, 2006; Fothergill & Peek, 2004; McCarthy, Canziani, Leary, Dokken, & White, 2001; Mileti, 1999; Wisner, Blaikie, Cannon, & Davis, 1994; Zahran, Brody, Peacock, et al., 2008). The SVI represents an easy and useful method to display complex realities in simple terms, through the production of new information that otherwise would not be visible or comprehensible (Vincent, 2004; Von Schirnding, 2002). For the computation of SVI the first stage concerns the selection of appropriate variables, to represent this complex notion of social vulnerability. This selection has always been point of controversy within the social science community (Cutter, Boruff, & Shirley, 2003). In this study, for examining social vulnerability of coastal cities in Mediterranean continental France, 10 specific variables for 2012 were collected from INSEE, for all 84 coastal communities (our unit of analysis), using the France Census and based on previous studies and the availability of demographic and other data (Table 2). The selected parameters reveal a potentially disproportionate confrontation of the disaster that can be induced by coastal erosion, in all its phases (protection ability before a disaster, evacuation compliance during the disaster and fast recovery after the disaster). In this

Table 1
Classification of CSI parameters in coastal sensitivity categories (Pendleton et al., 2004) and sources of data.

Variables	Sensitivity categories					Source | description
	Very low 1	Low 2	Moderate 3	High 4	Very high 5	
a	Rocky, cliff coasts	Medium cliffs, indented coasts	Low cliffs, alluvial plains	Cobble beaches, lagoons	Barrier beaches, deltas, beaches	Google Earth/National geological maps, (1: 50.000), 2011 http://portal.onegeology.org/
b (%)	> 12	12–9	9–6	6–3	< 3	*SRTM* (*CGIAR-CSI*) 90 m resolution, 2004
c (mm/yr)	< 1.8	1.8–2.5	2.5–3.0	3.0–3.4	> 3.4	Satellite measurements (1992–2013), EEA, 2014 (database *AVISO*)
d (m/yr)	> 2.0	1.0–2.0	− 1.0–1.0	− 2.0 to − 1.0	≤ 2.0	*Géoportail*/Google Earth (1: 68,244), 1977 and 2015
e (m)	> 6.0	4.0–6.0	2.0–4.0	1.0–2.0	< 1.0	National Hydrographic Service (*SHOM*), 2016
f (m)	< 0.55	0.55–0.85	0.85–1.05	1.05–1.25	> 1.25	National wave measurement data basis - *CANDHIS*. The measurements were carried out as part of collaboration between the *Port of Nantes St Nazaire*, *Ecole Centrale de Nantes* and *CEREMA*.

study, the disaster concerns possible floods caused by a combination of storm surges and coastal erosion, with an effect mostly on losses of property and goods (therefore effecting wellbeing), and less on human losses (death, injuries).

Several approaches can be used to calculate the SVI. For the evaluation of vulnerability in the US state of Louisiana, Flanagan et al. (2011) used the number of the determinant variables and the sum of the values of the normalized variables, even though they are expected to be strongly correlated. As stated in their study, the number of determinant variables is useful in order to focus on the cities with many vulnerable population groups, while the vulnerability exported only by the average of the variables may be covered by the offsetting of high prices with low prices. In this study, the number of the determinant variables and the average of the values of the normalized variables are taken into consideration. The combination of these two, which constitutes the SVI, is done with the average of their normalized values (Eq. (2)). For the determinant variable, the variable with a value greater or equal to 1/2 of the standard deviation from the mean value is chosen. The normalization of the selected data-variables in a uniform scale, in order to be comparable, was necessary. The method used was *Z*-score normalization, i.e. the distance of each value from the mean value in standard deviation quantities.

SVI math equation.

$$\mathrm{SVI} = (\mathrm{A} + \mathrm{B})/2 \tag{2}$$

where A = the average of the values of the normalized variables that were taken into consideration after their normalization using Eq. (3) and B = the number of the determinant variables after their normalization using Eq. (3).

Z-score normalization

$$(\mathrm{Z}) = \frac{(\mathrm{x} - \mu)}{\mathrm{sd}} \tag{3}$$

where: (x): initial variable values, (μ): the mean value of the variable values, (sd): the standard deviation of the variable values.

The same method was also implemented in the final results of both indexes and their categorization in five sensitivity/vulnerability categories was based on standard deviations from the mean value: lower (≤ 1 Std. Dev.) to higher (> 1 Std. Dev.). This method enables a better impression of the position for each value of CSI/SVI in the sequence of values and additionally, the average category can be easily defined, since all the values are expressed by their distance from the average price. All factors with positive values revealed higher levels of vulnerability, while the opposite decreased overall vulnerability. After the calculation, the linear character of the CSI was implemented in the SVI, in order to be able to compare the two indexes and present percentages of coastline that belong to each category of sensitivity and vulnerability (Table 3).

The localized tax revenues for 2010 were also used in our case studies (chapter 4) in order to compare social vulnerability and social inequality. Thus, this variable was not used in the calculation of SVI, but it was taken into consideration in the second phase of observations.

3. Results

Capturing the dynamics of the processes that produce socio-environmental vulnerability and highlighting emerging areas susceptible to sea-level rise.

3.1. Analyzing data on a regional scale

3.1.1. Observations on CSI

Coastal Sensibility Index - CSI contributes to the identification of the parameters which affect the coastal evolution. The calculated CSI values along the coastline of continental Mediterranean France range between 1.82 and 23.72. It was noted that a large part of the coastline of the study area, with a length of 747.7 km (45.7%), is classified as having very high sensitivity due to: low gradient coasts, sensitivity of the coastal landforms, highly erodible lithology (aprons of coastal alluvial fans and cones, pocket beaches) and high mean tidal range. This area includes almost all the Region of *Languedoc-Roussillon*, as well as the west part of the Region *Provence-Alpes-Côte-d'Azur*, where the Regional Parc of *Camargues* (municipality of *Arles* and *Saintes Maries de la Mer*) is located. Some smaller parts of very high sensitivity are located in the Region of *Var,* in the city of *Hyères* and in the Region of *Alpes Maritimes* in the cities of *Cannes* and *Nice*. In addition, 4.6% (75.3 km), 13.39% (219.19 km), 30.11% (492.7 km) and 6.17% (101.33 km) of coastline are classified as having respectively a high, moderate, low and very low sensitivity. In terms of the socio-economic implications related to the anticipated sea-level rise, most of the coastal urban and tourist areas are concentrated in the above-mentioned highly and very highly sensitive coastal segments.

3.1.2. Observations on the SVI

While the spatial distribution observed for the very high coastal sensitivity presents a relatively strict limit, the 14 municipalities (16.7%) characterized as socially most vulnerable, appear scattered in our analysis unit (Fig. 2). The majority of the municipalities (33.3%) reveal moderate levels of social vulnerability, while 11 of the total (13.1%) present high levels of social vulnerability. Municipalities classified as the least socially vulnerable are also spread all across our analysis unit, with 22.6% of them presenting low social vulnerability, and 14.3% belonging to the very low socially vulnerable category. Additionally, to the East, the *Côte d'Azur* (*Cap Bénat*, *Bormes-les-Mimosas*, *Rayol-Canadel-sur-Mer*, *La Croix-Valmer*, *Saint-Tropez*, *Sainte-Maxim*) is still characterized by the elitism of its vacationers and residents, may ensure low levels of social vulnerability in these areas.

Table 2
Selection and description of SVI parameters and cited literature.

Social and demographic variables		Prevention	Coping during a disaster	Recovery	Cited literature	Description
Extremes of ages	Population < 14 years old	–	–	–	Hewitt, 1997; Buckle et al., 2000	Generally extremes of age may have difficulties in preventing a disaster and mobility constraints during and after a disaster.
	Population > 75 years old	–	–	–	Buckle et al., 2000; Ngo, 2001	
Sex	Women		–/+	–	Cutter, 1996 Blaikie, Cannon, Davis, & Wisner, 1994 Morrow & Phillips, 1999 INSEE – Data 2014 - Observatory on inequalities	Women may have difficulties in recovering after lodging damages mainly due to lower wages. In France men earn 23% more than women.
Family structure	Single parent family	–	–	–	Blaikie et al., 1994 Heinz Center for Science, Economics, and the Environment, 2000	They often have limited finances to support their dependents before, during and after a disaster.
	Family with > 2 children	–	–	–	Puente, 1999 Heinz Center for Science, Economics, and the Environment, 2000	
Property	Tenants	–		–	Heinz Center for Science, Economics, and the Environment, 2000	They often lack of options after lodging damages as well as financial support since they do not own the destroyed property they live in.
City Structure	Average density (inhabitants/km^2)		–		Mitchell, 1999 Cutter, Mitchell, & Scott, 2000	High density areas perplex evacuation during a disaster.
Economic Status	Unemployed	–		–	Heinz Center for Science, Economics, and the Environment, 2000	Unemployed population is usually dependent on social services for survival, they may not have financial ability to prevent a disaster and they require additional sustenance for recovering after one.
Socio-EconomicStatus	No education	–		–	Heinz Center for Science, Economics, and the Environment, 2000	No education and different nationality may cause inability to prevent a disaster and to access recovery information, as well as post-disaster funding.
	Foreigners	–		–	Pulido, 2000 Peacock, Morrow, & Gladwin, 2000	

Table 3
Categories and percentage of SVI and CSI of each county's coastline.

Region	County	Coastline (%)	Categories of vulnerability/sensitivity				
			Very low 1	Low 2	Moderate 3	High 4	Very high 5
Languedoc-Roussillon	*Pyrénées-Orientales*	SVI	0	19.62	**57.51**	9.74	13.13
		CSI	37.5	0	0	0	**62.5**
	Aude	SVI	22.35	**36.25**	13.46	19.38	8.56
		CSI	0	0	9.57	0	**90.43**
	Hérault	SVI	6.57	21.56	**38.68**	12.81	20.38
		CSI	0	0	0	0	**100**
	Gard	SVI	0	0	**100**	0	0
		CSI	0	0	0	0	**100**
Provence-Alpes-Côte d'Azur (PACA)	*Bouches-du-Rhône*	SVI	10.21	0	34.59	7.47	**47.73**
		CSI	0	**47.27**	13.62	0	39.11
	Var	SVI	15.96	13.91	**45.01**	14.45	10.67
		CSI	0	**43.66**	23.7	22.58	10.06
	Alpes Maritimes	SVI	0	19.43	15.77	27.52	**37.28**
		CSI	**36.47**	**28.84**	**9.77**	**0**	**24.92**

In bold we notice the higher percentages of social vulnerability and coastal sensitivity for each region.

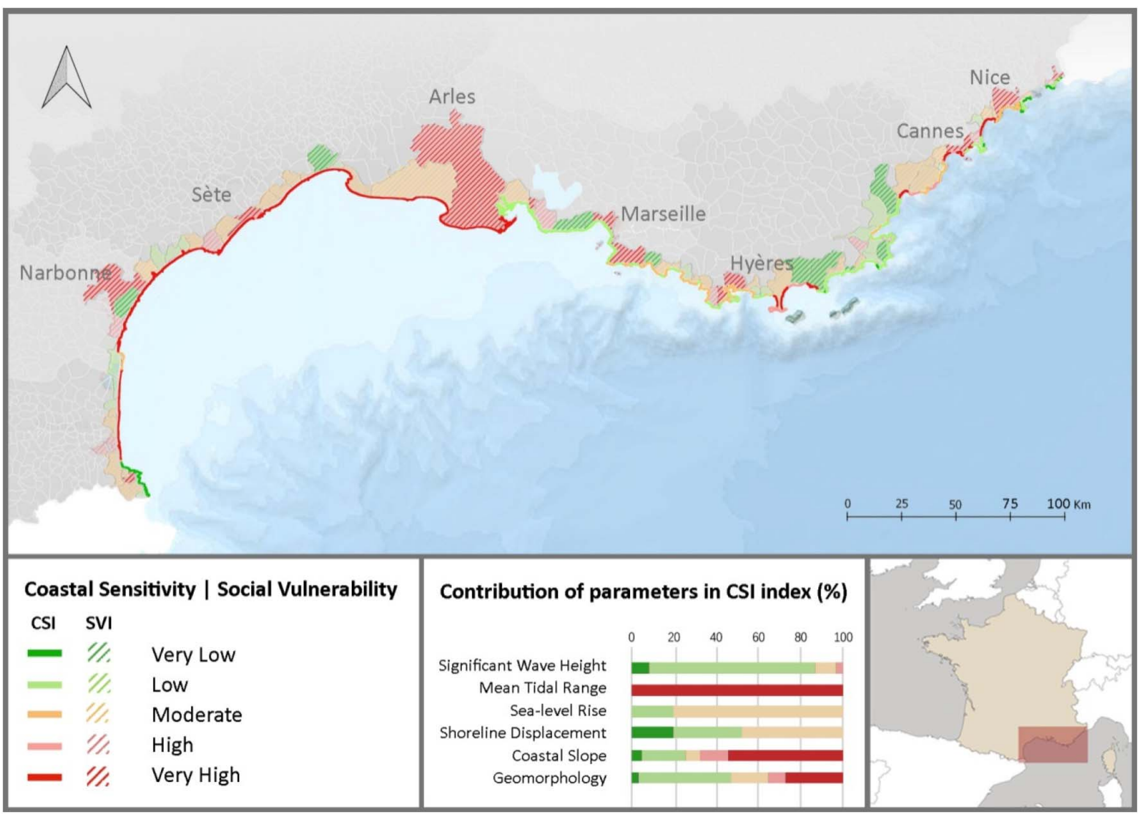

Fig. 2. Superimposing CSI and SVI.
Source: INSEE, Amante, and Eakins NGDC ETOPO1 (2010), modified by author.

3.2. Comparison of both indices in county scale

The distribution of scores by county for both SVI and CSI indexes enables a preliminary evaluation of susceptibility at the level of continental Mediterranean France, in order to prioritize coastal management. Therefore, Table 3 presents the percentage of the coastline of every county that belongs to each category of coastal sensitivity and social vulnerability (from 1 = very low to 5 = very high). Hence, a first image of the most susceptible counties can be accomplished while the link between the two indices can also be examined. We can observe that the most physically susceptible county is *Hérault*, whose entirety is characterized by very high levels of coastal sensitivity in erosion (*Gard* county is not characterized as the most vulnerable, since it only has one coastal municipality), while *Aude* and *Pyrénées-Orientales* follow with 90.43% and 62.5% of very high coastal sensitivity respectively. This occurs mainly due to their coastal segments (alluvial, sandy beaches) that had already caused erosion problems in the past. While *Hérault* county is the most physically susceptible, the most socially vulnerable

Table 4
Top 5 socially vulnerable municipalities and their determinant variables.

Determinant Variables	Top 5 socially vulnerable municipalities				
	Port-de-Bouc	Cannes	Marseille	Toulon	Nice
Average Density					
Tenants					
No degree					
Unemployment					
Population <14 years old					
Population >75 years old					
Families > 2 children					
Single Parents					
Women					
Foreigners					
Total of determinant variables	6	8	5	6	6

Ranking: High Low

Table 5
Coastal sensitivity for municipalities with highest and lowest values of social vulnerability.

County	Municipality with Highest SVI value	SVI value	CSI value	Municipality with Lowest SVI value)	SVI value	CSI value
Pyrénées-Orientales	*Port-Vendres*			*Cerbère*		
Aude	*Narbonne*			*Gruissan*		
Hérault	Sète			*Mauguio*		
Bouches-du-Rhône	*Toulon*			*Roquebrune-sur-Argens*		
Var	*Cannes*			*Théoule-sur-Mer*		
Alpes Maritimes	*Port-de-Bouc*			*Sausset-les-Pins*		

Categories of vulnerability/sensitivity: Very High Moderate Low Very Low

county is *Bouches-du-Rhône* (47.73% Very High Social Vulnerability), followed by *Alpes Maritimes* (37.28% Very High Social Vulnerability).

3.3. Analyzing data on a municipal scale

3.3.1. Socially vulnerable municipalities

Subsequently, in order to observe the hidden aspects of social vulnerability, the top five socially vulnerable municipalities and their determinant variables were collected (Table 4). It was noticed that their social vulnerability is derived from the different numbers and orders of the determinant variables. For three of the five top vulnerable municipalities (*Cannes*, *Toulon* and *Nice*) their main determinant variable is average density. However, for the totality of the studied shoreline this parameter appears in the bottom of the list. Concerning the rest of the determinant parameters, the order in which they influence the final result of social vulnerability for each municipality is not specified – nor can it be recorded. Therefore, social vulnerability has an interactive nature, well-presented through the fact that the parameters contribute differently to the overall vulnerability for each municipality. It may also be observed that similar high values of social vulnerability in different municipalities do not reflect a similar order in the contribution of each parameter to the overall social vulnerability (same determinant variables). Furthermore, regarding the spatial distribution of the top 5 socially vulnerable municipalities, two of them belong to the County of *Alpes Maritimes* (*Cannes* and *Nice*), two in the County of *Bouches-du-Rhône* (*Marseille* and *Port-de-Bouc*) and finally one in the County of *Var* (*Toulon*).

3.3.2. Socio-environmental vulnerability for municipalities

After superimposing the two indexes, the socio-environmental vulnerability of the municipalities emerges. In order to explore these typologies in cities, the municipalities with the highest and lowest values of social vulnerability and their coastal sensitivity are presented in Table 5. *Cannes*, *Sète* and *Narbonne* are characterized as having an accumulation of coastal sensitivity and social vulnerability, as they present the highest value (value 5) for both SVI and CSI indexes (Table 5). While for *Cannes* the average density, followed by family structure (single parent family) plays an essential role in social vulnerability, for *Sète* and *Narbonne* family structure and house tenancy are the key elements for their social vulnerability. On the other hand, there are examples like *Gruissan* and *Mauguio* which associate a very high CSI value with low social vulnerability rates (Table 5). This is mainly due to the homogeneity of these cities, where predominately French, middle-class residents are living in owner-occupied housing. For all these municipalities, their coastal sensitivity is mainly due to the alluvial character of their coasts, which tend to be sensitive to erosion in an anticipated sea-level rise.

4. Discussion

The first results from the application of the two indexes offer a preliminary assessment on a county and municipality scale and an interpretation of problematic areas. In order to prioritize them, a finer scale analysis was necessary. Thus, 3 case studies were selected, based on their socio-environmental vulnerability: areas of high levels of coastal sensitivity in conjunction with low levels of social vulnerability; areas where both social vulnerability and coastal sensitivity occur; and areas where social vulnerability presents high levels but coastal sensitivity does not. Afterward, a descriptive analysis took place, using IRIS[1] (infra-communal) data from INSEE, when possible. IRIS data allows for finer evaluation in the districts of each municipality, observing the

[1] The IRIS data (Ilots Gathered for Statistical Information) is a sub-municipal zoning for any town of > 5000 inhabitants, which support the investigation of social correlations between its districts.

existing situation on the coastal front. In doing so, it can be investigated if the results such as those presented in Fig. 2 and in Table 5 (municipality-level), are in accordance with the socio-environmental vulnerability of the coastal districts for the selected municipalities. This way a critical analysis can be conducted using the results on a county and coastal district scale, in order to assist local decision makers in coastal management and adaptation to climate change.

4.1. First case study – municipalities of Narbonne, Gruissan, Port-la-Nouvelle

Our first case studyt (Fig. 3) concerns the municipalities of *Port-la-Nouvelle*, *Narbonne* and *Gruissan*. Although they are neighboring towns, *Gruissan* presents low levels of social vulnerability, while *Narbonne* and *Port-la-Nouvelle* present very high and high levels of social vulnerability respectively. Their coastal sensitivity to erosion is very high, mostly due to their alluvial coastal character. Regarding their social vulnerability, it should be noted that *Narbonne* is a much bigger municipality, with all the social inequalities that this entails. While the city of *Narbonne* scores high percentages for most of the vulnerable groups (single parent families, the unemployed and unskilled), the district of *Narbonne-Plage* presents a contrasting picture. The median income of *Narbonne-Plage* is higher than the national average and no high rates of vulnerable groups are observed. This area is mostly a tourist destination (the population is 25 times higher during summer). For the other two municipalities, there are no IRIS data, due to their size (definition of IRIS). However, it is possible to formulate a comparative picture between them. *Gruissan* was originally a fishing village, but is now a major tourist attraction for the middle and upper social classes, because of the miles of beaches and the facilities that it offers (yachting marina and holiday apartment buildings around the palm-lined quays). On the other hand, *Port-la-Nouvelle*, has an intense industrial character, which prevents its development as an upper and middle-class destination for tourism or residence purposes. In terms of their economic status *Narbonne-Plage* concentrates the highest income households, *Gruissan* follows, while *Port-la-Nouvelle* is last. It was observed that the SVI scores presented for a municipality may not actually represent its coastal front. Thus, for the municipality of *Narbonne* a differentiated spatial distribution of social vulnerability in its interior is noted, since its coastal district presents lower levels of social vulnerability than the municipality as a whole.

4.2. Second case study – municipalities of Arles, Port-Saint-Louis-du-Rhône, Fos-sur-Mer, Port-de-Bouc, Martigues

Our second case study (Fig. 4) includes municipalities with both social vulnerability and coastal sensitivity (*Arles*, *Port-Saint-Louis-du-Rhône*) and others with social vulnerability but without coastal sensitivity (*Fos-sur-Mer*, *Port-de-Bouc and Martigues*).

- While *Arles* is the largest municipality in France, 80% of its territory is covered by Natura 2000 sites. The Camargue Regional Park (100,000 ha and 75 km of coastline), located on the Mediterranean, in the *Rhône* Delta, extends over 3 municipalities: part of the municipalities of *Arles* (district of *Salin-de-Giraud* included) and *Port-Saint-Louis-du-Rhône* and the whole municipality of *Saintes-Maries-de-la-Mer*. *Salin-de-Giraud*, the most populated village of the municipality of *Arles* (2100 inhabitants), which is also the closest to the coastal front, concentrates low levels of vulnerable groups and households with a median income above that of its municipality. *Port-Saint-Louis-du-Rhône* is a noticeably smaller municipality and its history is affected by its neighboring municipality of *Fos-sur-Mer* (Observatoire Ouest Provence, 2010).
- The creation of the industrial- port zone in *Fos-sur-Mer* in the 1970s resulted in the decline of the commercial port of the town whose activities were transferred to the West basins of the Grand Port Maritime of Marseille-GPMM (Observatoire Ouest Provence, 2010).
- The coastal district of *Malebarge*, which is faced with high levels of vulnerable groups, represents nearly 95% of the municipality territory, but the majority is consisted of natural areas.
- In *Fos-sur-Mer*, a very large part of the town (about 80%) is composed of the industrial port area, positioned to the West and North of the municipality. The higher concentration of lower income households is located in the urban central band (coastal district of *Village-Plage*). This area concentrates plenty of vulnerable groups in

Fig. 3. First case study – municipalities of *Narbonne*, *Gruissan*, *Port-la-Nouvelle*.
Source: localized tax revenues 2010 – INSEE (http://sig.ville.gouv.fr/Cartographie/13077), IRIS limits (www.data.gouv.fr), Google Earth, modified by author.

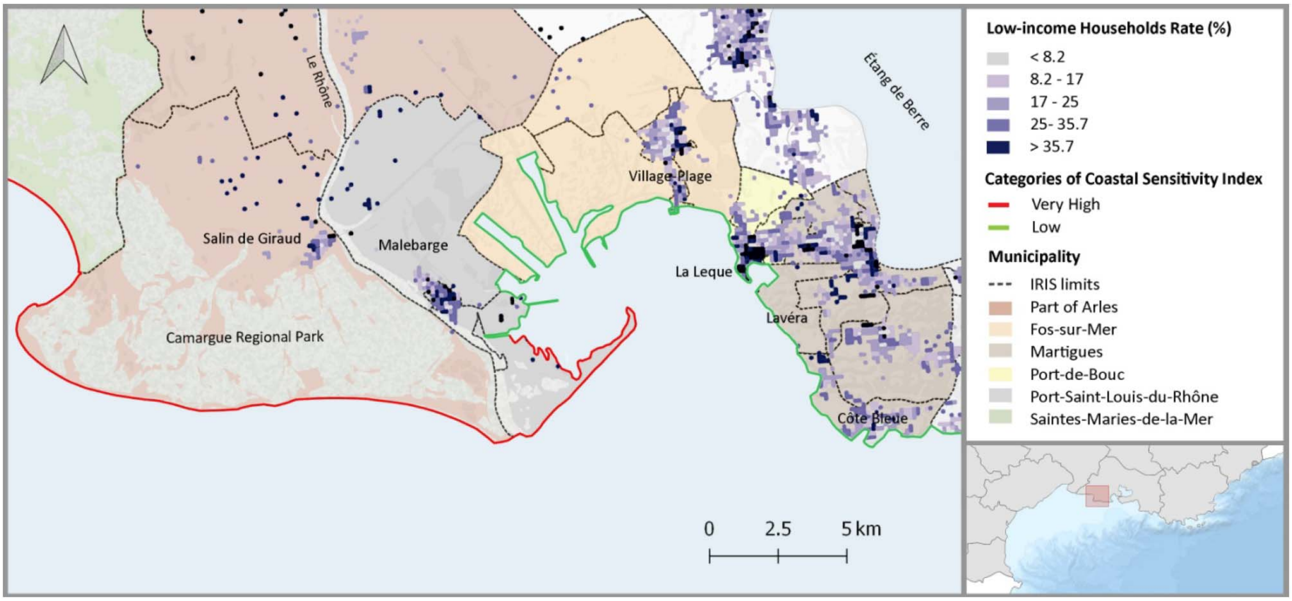

Fig. 4. Second case study – municipalities of *Arles*, *Port-Saint-Louis-du-Rhône*, *Fos-sur-Mer*, *Port-de-Bouc*, *Martigues*.
Source: localized tax revenues 2010 – INSEE (http://sig.ville.gouv.fr/Cartographie/13077), IRIS limit (www.data.gouv.fr), Google Earth, modified by author.

a rate above the average of the municipality (population > 75 years old, population < 14 years old, women, foreigners).

- *Port-de-Bouc* also concentrates its lower income households in its two coastal districts (*La Leque* and the *Center*). Furthermore, *La Leque* district presents a very high rate above the municipal average (20%) of unemployment (34.9%) and single parent families (33.2%).
- The municipality of *Martigues* is a total of 7144 ha including 697 ha of forests and 40 km of sea including 11 straight on the Mediterranean coast. From its two coastal districts (near the Mediterranean), *Lavéra* district has no population (750 ha of industrial area). On the other hand, *Côte Bleue* district is made up of high-income households, with no particular high levels of vulnerable groups.

The above-mentioned municipalities present different coastal sensitivity to erosion that arises from different coastal characteristics. We observe low gradient and highly erodible coasts, with marshy fields and alluvium soil, that cause high sensitivity (*Arles*, *Port-Saint-Louis-du-Rhône*, Camargue Regional Park), as much as white limestone (*Martigues*-Côte bleue) and artificial structures (*Fos-sur-Mer*, *Port-de-Bouc*), that cause low sensitivity to erosion due to sea-level rise.

Similar to *Narbonne* the municipality of *Arles* presents a differentiated spatial distribution of social vulnerability in its interior, mainly due to the low concentration of population in its coastal district (since the National Park of Camargue occupies almost the entire coastal front). Additionally, for *Fos-sur-Mer* and *Martigues* municipalities the population distribution in specific districts leads to questionable results concerning the municipality's coastal front. *Fos-sur-Mer* gathers socially vulnerable groups in its unique inhabited coastal district, while *Martigues*' inhabited coastal district is socially not as vulnerable as the municipality. For both these municipalities the coastal sensitivity to erosion is low, but the defining conditions differ. The artificial structure of *Fos-sur-Mer* (port) decreases the sensitivity, while a principal reason for low sensitivity in *Martigues* is the lithology (limestone). On the other hand, there are cases where a municipality's and coastal district's social vulnerability coincide. For *Port-de Bouc* and *Port-Saint-Louis-du-Rhône* the coastal districts are the most socially vulnerable (although for the second, there are no large percentages of population concentrated in its coastal limit).

Indeed, the *Camargue* is one of the most fragile French coastal areas facing the vagaries of climate change (high sea surges and waves). The low and sandy topography of this costal deltaic zone in conjunction with the numerous human activities (tourism, rice and salt production) makes this area of strong economic stakes particularly sensible to the risks of erosion, submersion and therefore inundation (Sabatier, Samat, Ullmann, & Suanez, 2009; Ullmann & Sabatier, 2010). The most remarkable storm events noticed in the area were in 1982 and 1997, as well as in 1985, where the tsunami unfortunately caused one death, 10 injuries and > 1000 disaster victims (P.P.Ri inondation sur la commune des Saintes-Maries-de-la-mer, 2016). For the municipality of *Saintes-maries-de-la-Mer*, these three events have been the subject of natural disaster. It should be noted that during the storm of 1982 the water level reached the value of 70 to 80 cm above the natural ground in Saintes-Maries-de-la-Mer (P.P.Ri inondation sur la commune des Saintes-Maries-de-la-mer, 2016). More recently, and to a lesser extent, near-shore areas have been affected by sea-level rise caused by storms in 2002, 2011 and 2014. Areas in the immediate vicinity of the *Saintes-maries-de-la-Mer* coast are frequently subject to flooding due to coastal erosion and marine submersion (P.P.Ri inondation sur la commune des Saintes-Maries-de-la-mer, 2016).

4.3. Third case study – municipalities of Cannes and Nice

Our third case study (Fig. 5) includes two municipalities, *Cannes* and *Nice*, where both social vulnerability and coastal sensitivity are present – but on different levels. First, the prevailing conditions on their coastal fronts differ. *Cannes* has experienced erosion problems exit since 1961, when 100,000 m^3 of pebbles were placed on *Croisette Plage*, in one of the earliest beach nourishment efforts (Pranzini & Williams, 2013). Although *Nice* also has erosion problems, its CSI value is at a moderate level, in relation to *Cannes*. The pebbles have been repeatedly replaced over the past 30 years, and today the beach level is generally under control, although extreme waves may be impacting the shoreline (Pranzini & Williams, 2013). Regarding the SVI, these municipalities belong to the very high level category of social vulnerability. However, for both of them, this high level of SVI is mainly due to their urban density and less to the economic, cultural and family insecurity of the inhabitants. Regarding SVI, the municipality of *Cannes* is socially more vulnerable than *Nice*. However, the majority of the *Cannes* coastal front

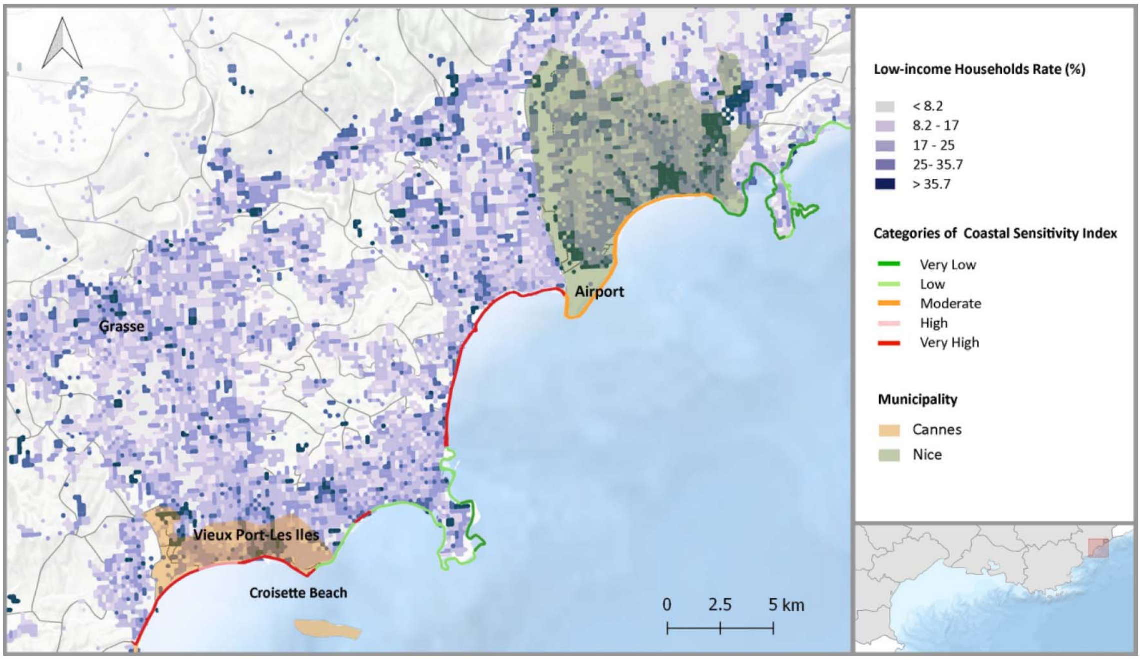

Fig. 5. Third case study – municipalities of *Cannes* and *Nice*.
Source: localized tax revenues 2010 – INSEE (http://sig.ville.gouv.fr/Cartographie/13077), IRIS limits (www.data.gouv.fr), Google Earth, modified by author.

is characterized by higher income households (37.5% of coastal districts are below national median income), in contrast to *Nice*, where the majority of lower income households (60% of coastal districts are 21.30% below national median income) have developed closer to the sea. For *Cannes*, the *Vieux Port-Les Iles* district comprises a high rate of vulnerable groups (unemployed and unskilled, foreigners, single parent families). This district is also the one that has the lower incomes (16,446) in comparison with all the other coastal districts. For *Nice*, the less socially favorable areas are contained in its west coastal districts, those closer to the airport. There we can observe high rates of foreigners, the unskilled and the unemployed, but not significantly high density. On the other hand, the less vulnerable districts, situated in the center/east coastal front, present very high density, but moderate-to-low rates of vulnerable groups. In the selected case study, it can be observed that the expressed high levels of social vulnerability, mostly due to average density, do not reflect social inequalities (low income, unskilled).

5. Conclusion

Considering the globally growing interest in understanding the nature of disasters, the scientific community is focusing attention on the underlying processes linking natural and human systems. As climate change impacts are inextricably associated with social vulnerability, any impact assessment must be also viewed through a social lens. In environmental change social relations are a key element of policy agendas for resilience research. Therefore, adaptation efforts should depend on preliminary vulnerability assessments. Almost half of the coastal continental Mediterranean part of France (all the Region of *Languedoc-Roussillon*, part of the Region of *Provence-Alpes-Côte-d'Azur*) is under continuous pressure, with intense erosion problems. It is therefore necessary to prioritize the policy-makers' directions.

The aim of the research was to identify the parameters and conditions involved, that represent the most dynamic processes in risk exposure. Therefore, a comparison of the results for two widely used empirical indexes – a CSI (Shaw et al., 1998) and a SVI (Flanagan et al., 2011) – applied to Mediterranean continental France was carried out, in order to explore the complex notion of vulnerability to climate change. The outcome raises questions about the coastal cities of Mediterranean continental France and the prioritization of the municipalities in accordance with their need for further resilience investigations. Since this was the first such superimposition for the study area, the result helps highlight the variables which contribute most to the coastal sensitivity and social vulnerability of a city, in order to adapt to climate change through reflecting on sustainable development.

Through the focus on the selected areas, it was noticed that the absence of the accumulation of social vulnerability and coastal sensitivity is mainly observed in a localized manner, based not so much on considerations of social justice as on a social and spatial segmentation. In addition, the relation between social vulnerability and social inequalities is not systematic. While social inequalities always lead to social vulnerability, since the uneven distribution of a society's resources (income, unequal access to education etc.) results in specific social statuses of individuals within a group or a socio-ecological system, the opposite is not always valid. The SVI is based on several parameters and its rate can be high without necessarily incurring high values among all the parameters used (as in the case of *Cannes* and *Nice*). Furthermore, as the research led to a finer scale of analysis it was noted that in certain cases the municipality scale results for social vulnerability distorted the true situation of the coastal front, due to its differentiated spatial distribution in the interior of the municipality. Thus the socio-environmental vulnerability of a place varies according to the study's scale, and there is a possibility for coastal districts to switch categories of socio-environmental vulnerability compared to their municipality. Therefore, the interest lies in the recognition of the most vulnerable coastal districts of cities, in conjunction with the coastal sensitivity, in order to prioritize the efforts for improvement. Additionally, the need to develop a concise approach with more accurate social-demographic, economic and geophysical data is essential. This will allow a simpler and more relevant reading of the territory on a more geographically correct scale.

Determining vulnerability is difficult because of the complexity of the systems that are involved in the procedure. The chosen parameters for both indexes were based on the existing literature and open or free

data. Although the use of open or free data enables new approaches through better access to datasets that were not necessarily available until now, their accuracy, completeness or formality must always be taken into consideration. In addition, all factors were not available in open data and a preparation in spatial and temporal coherence was carried out beforehand in order to disseminate the results. Additionally, due to the fact that all CVI parameters refer to a regional scale, while for SVI municipality-level datasets were used, the indexes cannot be synthesized into one, because of their spatiotemporal differences. However, these empirical indexes enable a preliminary assessment at county level, as a first step for selecting case studies for further investigation. For this reason, the research should be treated as a prospective one and the results as a state of being, wherein the selected parameters operate as characteristics that may influence the conditions that make people and therefore communities susceptible to the effects of potential hazards. A validation of the results, including field validation (independent coastal erosion data set) and social surveys should be implemented in the procedure for creating a more accurate image of vulnerability.

For all the above-mentioned reasons, the development of a spatial GIS database that collects and elaborates the variables involved in the calculation of both indexes on various scales is necessary. Moreover, new parameters can be implemented in the procedure of both indexes, in order to assist planners in highlighting vulnerable coastal municipalities. The CVI could be renewed and expanded further, in order to incorporate new available data/parameters, including elevation data, storm surge, sediment budget, etc. Furthermore, since coastal sensitivity is affected to a large extent by humans, new variables that factor in human activity, such as artificial beach nourishment, beach control structures (groynes and seawalls), land uses (roads, buildings, utilities) could also be implemented in the procedure. For SVI, the methodology can be upgraded, by ameliorating the number of the considered variables, as well as by determining more accurate geo-referenced standardized databases (local level). In addition, the separation of the parameters used in the process of social vulnerability can lead to a better evaluation of the actual need for adaptation of Mediterranean cities to climate change.

In fact, the SVI used in this research combines a number of variables that belong to very different registers, limiting the possibility of apprehending them as a homogeneous whole. Moreover, faced with the various risks, there is not a generic social vulnerability but contextualized social vulnerabilities. Corollary, depending on whether it is prevention-protection, disaster management or post-disaster repair, the different social vulnerabilities do not intervene in the same way. Therefore, the importance lies less in the social vulnerability *sui generis* and more in the influence of different socioeconomic and demographic variables on the actors' capacities to act. For example, an elderly but wealthy and influential person can finance himself for protection works (or has the ability to get them financed) (Claeys et al., 2017), but his wealth will not allow him to run away when a tsunami occurs, an advantage that a poor but young and healthy person has. Thus, in the global SVI, sub-categories should be added, that will permit the differentiation between the capacities of actors and individuals concerning: their financial resources (economic capital), their networks of influence and solidarity (social capital) and their physical ability (physical fitness, health).

Finally, the accuracy of the methodology can be improved for both indexes with the assignment of weights, although this should involve a panel of experts, in order to obtain the most objective results possible. The shocks experienced by the social-ecological system and its response, can guide the analysis of actions to reduce the risk, augment the capacity of cities for adaptation in this new climate era and enhance general well-being.

References

Adger, N. W. (1999). Social vulnerability to climate change and extremes in coastal Vietnam. *Word Development, 27*(2), 249–269.
Adger, N. W. (2006). Vulnerability. *Global Environmental Change, 16*, 268–281. http://dx.doi.org/10.1016/j.gloenvcha.2006.02.006.
Alwang, J., Siegel, P. B., & Jorgensen, S. L. (2001). *Vulnerability: A view from different disciplines* (Social Protection Discussion Paper No. 0115)Human Development Network. The World Bank.
Amante, C., & Eakins, B. W. (2009). *ETOPO1 1 arc-minute global relief model: Procedures, data sources and analysis. NOAA Technical Memorandum NESDIS NGDC-24.* National Geophysical Data Center, NOAAhttp://dx.doi.org/10.7289/V5C8276M (last access: 22/7/2016).
Beck, U. (1992). *Risk society toward a new modernity.* London: Sage.
Bertran de Balanda, S. (2014). Paysage industriel et imaginaire à Martigues, Rives méditerranéennes [En ligne], 47|2014 (published online on 15 February 2015, consulted on 3 September 2014) http://rives.revues.org/4578.
Blaikie, P., Cannon, T., Davis, I., & Wisner, B. (1994). *At Risk: Natural Hazards, People's Vulnerability, and Disasters.* London: Routledge.
Bolin, R., & Stanford, L. (1998). *The Northridge earthquake: Vulnerability and disaster.* London: Routledge.
Bottaro, A. (2014). *La villégiature anglaise et l'invention de la Côte d'Azur, In Situ [En ligne], 24|2014* (published online on 10 July 2014, consulted on 4 July 2016)http://insitu.revues.org/11060http://dx.doi.org/10.4000/insitu.11060.
Brauch, H. G. (2003). Natural disasters in the Mediterranean (1900–2001): From disaster response to disaster preparedness. In H. G. Brauch, A. Marquina, M. Selim, P. H. Liotta, & P. Rogers (Eds.). *Security and environment in the Mediterranean. Conceptualising security and environmental conflicts*Berlin-Heidelberg: Springer (forthcoming).
Buckle, P., Marsh, G., & Smale, S. (2000). New approaches to assessing vulnerability and resilience. *Australian Journal of Emergency Management, 2000*(15), 8–14.
Burton, C., & Cutter, S. L. (2008). Levee failures and social vulnerability in the Sacremento-San Joaquin delta area, California. *Natural Hazards Review, 9*(3), 136–149.
Cazenave, A., & Nerem, R. S. (2004). Present day sea-level change: Observations and causes. *Reviews of Geophysics, 42*, 3.
Claeys, C., Giuliano, J., Tepongning, M. H., Fissier, L., Rouadjia, A., Lizée, C., ... Marçot, N. (2017). *Une analyse interdisciplinaire des vulnérabilités socio-environnementales: Le cas de falaises côtières urbanisées en Méditerranée*.
Clavano, W. R. (2012). *A coastal vulnerability index for the Philippines using remote sensing data. 1*. Figshare.
Cutter, S. L. (1996). Vulnerability to Environmental Hazards. *Progress in Human Geography, 20*(4), 529–539.
Cutter, S. L., Mitchell, J. T., & Scott, M. S. (2000). Revealing the vulnerability of people and places: A case study of Georgetown County, South Carolina. *Annals of the Association of American Geographers, 90*(4), 713–737.
Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social Vulnerability to Environmental Hazards. *Social Science Quarterly, 84*(2), 242–261.
Daumalin, X. (2013). L'étang de Berre: un territoire dédié à l'industrie chimique. *Olivier Radakovitch (dir.), Lagun'E. Rencontres scientifiques autour de l'étang de Berre*(pp. 20–28). Aix-en-Provence: GIPREB.
Deboudt, P. (2010). (dir.)*Inégalités écologiques, territoires littoraux et développement durable.* Villeneuve d'Asq: Septentrion Presses Universitaires (409 p.).
Deldreve, V. (2015). *Pour une sociologie des inégalités environnementales.* Bruxelles: Peter Lang (243 p.).
Diez, P. G., Perillo, G. M. E., & Piccolo, C. M. (2007). Vulnerability to sea-level rise on the coast of the Buenos Aires Province. *Journal Coastal Research, 23*, 19–126.
Doukakis, E. (2005). Coastal vulnerability and sensitivity parameters. *European Water, 2005*(11), 3–7.
Dwyer, A. Z., Nielsen, C., Day, S., et al. (2004). Quantifying social vulnerability: A methodology for identifying those at risk to natural hazards. *Geosciences Australia Record, 14*, 20004.
EM-DAT (2012). *The OFDA/CRED international disaster database.* Brussels (Belgium): Université Catholique de Louvain.
Enarson, E., Fothergill, A., & Lohri, P. (2006). Gender and Disaster: foundations and directions. In H. Rodriguez, E. Quarantelli, & R. R. Dynes (Eds.). *Handbook of disaster research*(pp. 130–146). Springer.
Eurostat (2012). Products statistics in focus. Nearly half of the population of EU countries with a sea border is located in coastal regions - Issue number 47/2009. Retrieved from http://ec.europa.eu/eurostat/en/web/products-statistics-in-focus/-/KS-SF-09-047.
Fassin, D. (2009). *Inégalités et santé, Problèmes politiques et sociaux, Paris.* (La documentation Française).
Fassin, E. (2015). D'un langage l'autre: l'intersectionnalité comme traduction. *Raisons politiques, 2*(58), 9–24.
Flanagan, B. E., Gregory, E. W., Hallisey, E. J., Heitgerd, J. L., & Lewis, B. (2011). A Social Vulnerability Index for disaster management. *Journal of Homeland Security and Emergency Management, Vol. 8*(1), http://dx.doi.org/10.2202/1547-7355.1792. Available at: http://www.bepress.com/jhsem/vol8/iss1/3 (Article 3) .
Fothergill, A., & Peek, L. A. (2004). Poverty and disasters in the United States: A review of recent sociological findings. *Natural Hazards, 32*(1), 89–110.

Fraser, N. (2005). Reframing global justice. *New Left Review, 36*, 69.
Gornitz, V., & Kanciruk, P. (1989). Assessment of global coastal hazards from sea-level rise: Coastal zone '89. *Proceedings of Sixth Symposium on Coastal and Ocean Management* (pp. 1345–1359). Charleston, South Carolina: ASCE.
Gornitz, V. M., Daniels, R. C., White, T. W., & Birdwell, K. R. (1994). The development of a coastal risk assessment database: Vulnerability to sea-level rise in the U.S. southeast. *Journal of Coastal Research,* (12), 327–338.
Gorokhovich, Y., Leiserowitz, A., & Dugan, D. (2014). Integrating coastal vulnerability and community-based subsistence resource mapping in Northwest Alaska. *Journal of Coastal Research, 30*(1), 158–169 (Coconut Creek, Florida).
Gortnitz, V. (1991). Global coastal hazards from future sea-level rise. *Palaeogeography, Palaeoclimatology, Palaeoecology, 89*, 379–398 (Global and Planetary Change Section).
Gualdi, S., et al. (2013). In A. Navarra, & L. Tubiana (Eds.). *Future climate projections. Chapter 3. Volume 1: Air, sea and precipitation and water. Regional assessment of climate change in the Mediterranean*.
Harvey, D. (1996). *Justice, nature and the geography of difference.* Oxford: Blackwell.
Heinz Center for Science, Economics, and the Environment (2000). *The hidden costs of coastal hazards: Implications for risk assessment and mitigation.* Covello, Cal.: Island Press.
Hewitt, K. (1997). *Regions of Risk: A Geographical Introduction to Disasters.* Essex: Longman.
The scientific basis: Contribution of working group I to the third assessment report of the intergovernmental panel on climate change. In J. T. Houghton, (Ed.). *Climate change* (pp. 525–582). Cambridge University Press.
INSEE (2010). *Revenus fiscaux localisés, RP2013 Exploitations Principales, RP2013 Exploitations Complémentaires, données communals et données infracommunales*.
IPCC (Intergovernmental Panel on Climate Change) (2013). Summary for policymakers. *Climate change 2013: The physical science basis*. Retrieved from http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf (Last access 9/2015) .
Jeftic, L., Milliman, J., & Sestini, G. (1992). *Climatic change and the Mediterranean. 645*. UNEP.
Karymbalis, E., Chalkias, C., Chalkias, G., Grigoropoulou, E., Manthos, G., & Ferentinou, M. (2012). Assessment of the sensitivity of the southern coast of the Gulf of Corinth (Peloponnese, Greece) to sea-level rise. *Central European Journal of Geosciences, 4*(4), 561–577. http://dx.doi.org/10.2478/s13533-012-0101-3.
Karymbalis, E., Chalkias, C., Ferentinou, M., Chalkias, G., & Magklara, M. (2014). Assessment of the sensitivity of Salamina and Elafonissos islands to sea-level rise. *Journal of Coastal Research,* (70), 378–384. http://dx.doi.org/10.2112/SI70-064.1.
Lélé, S. (1991). *Sustainable development a critical review. World development. Vol. 19, No. 6*, 607–621.
Levefre, H. (1991). *The production of space, Donald Nicholson-Smith trans.* Oxford: Basil Blackwell0-631-14048-4 (Originally published 1974).
Lewis, J. (1999). Development in disaster-prone places. *Studies of vulnerability*. London: Intermediate Technology Publication.
Lichter, M., & Felsenstein, D. (2012). Assessing the costs of sea-level rise and extreme flooding at the local level: A GIS-based approach. *Ocean & Coastal Management, 59*, 47–62.
Magnan, A., & Duvat, V. (2015). La fabrique des catastrophes “naturelles”. *Natures Sciences Sociétés, Vol. 23*(2), 97–108.
Mavromatidi, A., & Karymbalis, E. (2016). Assessment of susceptibility to sea-level rise in the coastal area of Pieria Prefecture. *Participation in 14th International Conference of the Geological Society of Greece, Thessaloniki, 25–27 May 2016*.
Mavromatidis, L. E. (2012). The aesthetic value of socio-cultural identities and the cultural dimension of the landscape. Human geographies. *Journal of Studies and Research in Human Geography, Vol. 6*(2), 15–21. http://dx.doi.org/10.5719/hgeo.2012.62.15 (ISSN online: 2067–2284/ISSN print: 1843-6587).
Mavromatidis, L. E., & Mavromatidi, A. (2012). *Re-inventing the ‘doubt’ of the ‘icon’: A virtual case study in a post-USSR (Union of Soviet Socialist Republics) country's capital. Urbani Izziv. Vol. 23*, 79–92. No. 2. (Slovenian Version, pp. 5–17) http://dx.doi.org/10.5379/urbani-izziv-2012-23-02-001 (ISSN print: 0353-6483/ISSN Online: 1855-8399) .
Mavromatidis, L. E., Mavromatidi, A., & Lequay, H. (2014). The unbearable lightness of expertness or space creation in the “climate change” era: A theoretical extension of the “constructal law” for building and urban design. *City, Culture and Society, Vol. 5*(Issue 4), 21–29. http://dx.doi.org/10.1016/j.ccs.2014.09.003.
McCarthy, J. J., Canziani, O. F., Leary, N. A., Dokken, D. J., & White, K. S. (Eds.). (2001). *Climate change 2001: Impacts, adaptation and vulnerability*. Cambridge: Cambridge University Press.
Meur-Ferec, C., Deboudt, P., & Morel, V. (2008). Coastal risks in France: An integrated method for evaluating vulnerability. *Journal of Coastal Research, 24*(2), 178–189.
Mileti, D. (1999). *Disasters by design: A reassessment of natural hazards in the United States.* Washington, D.C.: Joseph Henry Press.
Mitchell, J. K. (1999). *Crucibles of hazard: Mega-cities and disasters in transition.* Tokyo – New York – Paris: UN University Press.
Morrow, B. H., & Phillips, B. (1999). What’s Gender ‘Got to Do With It’? *International Journal of Mass Emergencies and Disasters, 17*(1), 5–11.
NASA (2014). *Shuttle radar topography mission (SRTM30 v.2) for topography (public domain).* JPL SRTMhttp://www.jpl.nasa.gov/srtm/ (last access: 22/7/2016).
Ngo, E. B. (2001). When Disasters and Age Collide: Reviewing Vulnerability of the Elderly. *Natural Hazards Review, 2*, 80–89.
Nussbaum, M. (2003). Capabilities as fundamental entitlements: Sen and social justice. *Feminist Economics, 9*(2–3), 33–59.
Observatoire Ouest Provence (2010). *Radioscopie de la Commune de Fos-Sur-Mer: La ville, ses quartiers et ses habitants*.
O'Keefe, P., Westgate, K., & Wisner, B. (1976). Taking the naturalness out of natural disasters. *Nature, 260*, 566–567.
Oliver-Smith, A. (2004). Theorizing vulnerability in a globalized world: A political ecologies perspective. In G. Bankoff, G. Frerks, & D. Hillhorst (Eds.). *Mapping vulnerability: Disasters, development and people*. London: Earthscan.
Peacock, W., Morrow, B. H., & Gladwin, H. (2000). *Hurricane Andrew and the reshaping of Miami: Ethnicity, gender, and the socio-political ecology of disasters.* Miami, FL: Florida International University, International Hurricane Center.
Pendleton, E. A., Thieler, E. R., & Williams, S. J. (2004). Coastal vulnerability assessment of Cape Hattaras National Seashore (CAHA) to sea-level rise. *USGS open file report. 1064*.
Picon, B. (2008). *L'espace et le temps en Camargue, Actes sud, Arles.* (304 p.).
Plan Bleu. Climate risk management tools: Towards a multi-scale coastal risk index for the Mediterranean. (2015). http://planbleu.org/sites/default/files/publications/notes28_en.pdf/ (Accessed 04.07.2016).
Plan de prevention des risques naturels previsibles (p.p.r.) inondation sur la commune des Saintes-Maries-de-la-mer. Article L562-1 du code de l'Environnement. (2016). http://www.bouches-du-rhone.gouv.fr/content/download/18630/115582/file/2016_04_rapport_pr/ (Accessed 09.07.2017).
Pranzini, E., & Williams, A. (2013). *Coastal erosion and protection in Europe.* London: Routledge.
Puente, S. (1999). Social vulnerability to disaster in Mexico City. In J. K. Mitchell (Ed.). *Crucibles of hazard: Mega-cities and disasters in transition* (pp. 295–334). Tokyo: United Nations University Press.
Pulido, L. (2000). Rethinking Environmental Racism: White Privilege and Urban Development in Southern California. *Annals of the Association of American Geographers, 90*, 12–40.
Reyes, S. R., & Blanco, A. C. (2012). *Assessment of coastal vulnerability to sea level rise using remote sensing (RS) and geographic information systems (GIS): A case study of Bolinao.* (Panganisan, Philippines, Melbourne, Australia).
Rulleau, B., Rey-Valette, H., Flanquart, H., Hellequin, A.-P., & Meur-Férec, C. (2015). *Perception des risques de submersion marine et capacité d'adaptation des populations littorales, VertigO – la revue électronique en sciences de l'environnement [En ligne], Hors-série 21 | avril 2015, mis en ligne le 20 février 2015, consulté le 17 septembre 2015.* http://vertigo.revues.org/15811http://dx.doi.org/10.4000/vertigo.15811.
Sabatier, F., Samat, O., Ullmann, A., & Suanez, S. (2009). Connecting large-scale behaviour with coastal management of the Rhône delta. *Geomorphology, 107*, 79–89.
Sachs, J. D., Mellinger, A. D., & Gallup, J. L. (2001). The geography of poverty and wealth. *Scientific America, 284*(3), 70–75.
Sagnes, J. (2001). L'aménagement touristique de la côté du Golfe du Lion (dir) In J. Sagnes (Ed.). *Deux siècles de tourisme en France*(pp. 27–53). Presses universitaires de Perpignan.
Shaw, J., Taylor, R. B., Forbes, D. L., Ruz, M.-H., & Solomon, S. (1998). Sensitivity of the coasts of Canada to sea-level rise. *Bulletin of the Geological Survey of Canada, 505*, 1–79.
Steinberg, T. (2000). *Acts of god: The unnatural history of natural disaster in America.* New York, USA: Oxford University Press.
Szlafsztein, C., & Sterr, H. (2007). A GIS-based vulnerability assessment of coastal natural hazards, state of Pará, Brazil. *Journal of Coastal Conservation, 11*, 53–66.
Taylor, D. E. (2000). The rise of environmental justice paradigm. Injustice framing and the social construction of environmental discourses. *The American Behavioral Scientist, 43*, 508–580.
Thieler, E. R., & Hammar-Klose, E. S. (1999). *National assessment of coastal vulnerability to sea-level rise, U.S. Atlantic Coast, U.S. geological Survey, open-file report.* 99–593.
Ullmann, A., & Sabatier, F. (2010). Types de temps et risque d”inondation et d’´erosion en Camargue : diagnostique et prévision au 21éme siècle (1993–2100). *EchoGéo, Pôle de Recherche pour l”Organisation et la diffusion de l”Information géographique. 2010. EchoGéo, Pôle de Recherche pour l”Organisation et la diffusion de l”Information géographique* (pp. 1–5).
UN (2000). *World urbanization prospects. The 1999 revision. Data tables and highlights.* New York: UN Population Division, Department of Economic and Social Affairs, United Nations Secretariat.
UNCHS, Habitat (2001). *Cities in a globalising world. Global report on human settlements 2001.* Nairobi: UNCHS.
Vincent, K. (2004). *Creating an index of social vulnerability to climate change for Africa, Tyndall center working paper 56*.
Von Schirnding, Y. (2002). *Health in sustainable development planning: The role of indicators. WHO/HDE/HID/02.11.* Geneva: World Health Organization (WHO).
Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (1994). *At risk: Natural hazards, people's vulnerability, and disasters.* New York: Routledge.
Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). *At risk: Natural hazards, people's vulnerability and disasters.* London: Routledge.
Yuval-Davis, N. (2015). *Situated intersectionality and social inequality, Raisons politiques. Vol. 58, No. 2*, 91–100.
Zahran, S., Brody, S. D., Peacock, W. G., et al. (2008). Social vulnerability and the natural and build environment: A model of flood causalities in Texas. *Disasters, 32*(4), 537–560.
NOAA - National Centers for Environmental Information. State of the climate: Global analysis for February. (2016). Retrieved from http://www.ncdc.noaa.gov/sotc/global/201602 (Published online March 2016).